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METHODOLOGY FOR INTEGRATION TESTING OF AIRCREW CLOTHING AND EQUIPMENT

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USAF SCHOOL OF AEROSPACE MEDICINE
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The Office of Public Affairs has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

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This report recommends a comprehensive range of tests for the integration and viability of an aircrew personal protective ensemble (PPE) or an item of PPE for use in an aircraft. It is emphasized that these tests are additional to any type test schedules for individual items of PPE. Tests described in this report should be completed satisfactorily before the item or assembly is submitted for flight test evaluation.

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METHODOLOGY FOR INTEGRATION TESTING OF AIRCREW CLOTHING AND EQUIPMENT

INTRODUCTION

Aircrew Personal Protective Equipment (PPE) can be defined as items worn, carried, or used by aircrew in the normal performance of their duties in flight and for emergency escape, location and survival. It is recommended that a PPE schedule should be produced by a suitable authority for each aircraft type which lists PPE items under two headings - one for items which are general wear and personal issue to aircrew; and the other for items which are on the aircraft inventory and remain in the aircraft. The PPE schedule for an aircraft type should also detail those items which are considered mandatory, and those items which are optional.

This report recommends a comprehensive range of tests for the integration and acceptance of a PPE or an item of PPE for use in an aircraft. It is emphasized that these tests are additional to any type test schedules for individual items comprising the PPE. Tests described in this report should be completed satisfactorily before the assembly or item is accepted for Service use.

Before the tests for a PPE item are scheduled, the designer/manufacturer should provide a detailed description of the equipment with reference to any Statement of Need (SON), and evidence of the extent to which the item and its components have been tested. The SON should detail those areas in design where a functional or mechanical failure of a component would seriously impair the performance of the assembly or the system.

The test schedule should be designed to show that the performance of each PPE item is not adversely affected by any other PPE item or interaction with the aircraft, seat, or harness assembly. The test results should show that the PPE does not adversely affect the efficient performance of aircrew personnel throughout the complete size range and throughout the full range of their duties and escape sequences. Particular attention should be given to the environmental stresses created by altitude, vibration, noise, temperature, and acceleration.

When any change is made to an item in an existing assembly, the designer should describe the change to the appropriate Service who should then agree on the range of additional and/or repeat tests appropriate before acceptance of the alteration.

An appropriate anthropometric range of personnel and/or dummies to be used in the tests should be decided before testing.

Appendix A details a tabulation of the essential factors which should be considered prior to and during the development and integration of aircrew clothing and equipment.

SCHEDULE OF TESTS

In the following tests, an item should be unacceptable if it constitutes an injury hazard, is hazardous to safe escape and survival, or detracts from the safe and efficient performance of normal aircrew duties. During tests, flying clothing pockets should contain those items normally carried in flight for the particular aircraft/role being covered, e.g. flip cards, maps, survival aids, and other personal equipment. Tests need to demonstrate that all fastenings, knobs, levers, and buckles can be operated in total darkness (blindfold) while wearing gloves appropriate to the PPE under test. The number of times any individual test is to be conducted should be decided by the appropriate authority. Physiological monitoring may need to be performed during environmental tests to ensure the safety of subjects taking part.

1. Effect on Procedures

These tests should be conducted to show the effect of the item or PPE on dressing, walk-out, entry, operating and routine and emergency egress procedures.

The various sequences and procedures should be carefully defined with reference to aircrew standard operating procedures for each applicable aircraft type. If necessary, the sequences and procedures should be documented using Task Analysis techniques, since data and information gathered at this stage will be useful ultimately for the preparation of training and procedure manuals.

a. Dressing. Subjects should dress in the appropriate PPE including the test item(s). Any effect on normal dressing procedures should be noted.

b. Walk-out and entry. Subjects dressed as for 1.a. should walk-out (or simulate walk-out) to the aircraft or mock-up, carry out appropriate real or simulated checks, and take up the appropriate crew station. Entry should be made by both ground access and integral ladders. Any effect of the item(s) should be noted, e.g. lack of mobility, increased thermal loading, interaction with aircraft structure. When a mock-up is used, a final acceptance test should be performed in an aircraft to confirm the results.

c. Strapping-in Procedures. A method of locating the eye datum for the appropriate aircraft role should be provided to ensure that each subject can place his eye in such a position. Additional tests may need to be performed with the subject's eyes positioned so as to more accurately reflect actual aircrew operating practices. After entering the aircraft, the subject should adjust the seat to the appropriate eye level, and where applicable, adjust the rudder pedals before commencing strapping-in drills. The subject should then strap into the seat. The compatibility of the seat restraint/parachute harness system with the PPE should be assessed. The length of straps, method of adjustment and connection will need to be determined. At this point, the method of connecting the man to his communication and life support systems should be examined, including hose and Mic/Tel lead routing and length. A sequence of actions for routine strapping into the seat (strapping-in drill) may need to be determined including the removal/stowage of any safety pins.

d. Normal Operating Procedures. With the subject strapped into the seat, assessment should be made of any interaction between the man, his PPE, and aircraft structure and seat during the performance of each maneuver needed to operate the seat systems in both normal and emergency situations.

(1) Assessment should be made of any interaction between the subject's head/helmet and the canopy and seat head rest over the full range of head movement. The accessibility of pockets, filled with all contents normally carried, when strapped into the seat should be assessed. The position of the eye level should be defined and the assessments made to ensure that the crewmember, with his eyes at the appropriate level, can accomplish adequate visualization of the head-up display, internal consoles and control panels, and external fields-of-view.

(2) An assessment of head movement and visual limitations, inside and outside of the aircraft, imposed by the PPE, the seat, the cockpit, and canopy should be made at varying seat positions which are practical for each subject, and specifically including at the defined eye-level position.

(3) With subjects seated at the defined eye-level position, the full range of aircrew movements possible, the use of all essential aircraft switches, and full control movements should be assessed. Additionally, the posture and mobility of subjects, and their ability to access the ejection seat emergency controls should be assessed under negative G_z conditions using an inversion wheel, with the harness both locked and unlocked. Additionally, helmet to canopy clearances should be assessed under both positive and negative G_z conditions.

(4) Combinations of possible combined control movements, such as full rudder, elevator, and aileron deflection to both similar and opposite sides, should be assessed. Any interference of control movements with each other, with the cockpit, seat, PPE items or with the subject's vision of essential instruments should be evaluated. All the above maneuvers should be attempted, where applicable, with the subject's anti-G trousers and pressure garments both fully inflated and deflated.

e. Anthropometric Limitations. While performing tests defined in paragraphs 1. and 2., any anthropometric limitations should be noted.

f. Drills Proposed. The following drills should be performed satisfactorily. Any adverse effects of the equipment under assessment should be noted.

(1) Normal Egress: Subjects should perform normal unstrapping and egress drills.

(2) Emergency Ground Egress: Subjects should perform rapid egress drills to simulate leaving the aircraft on the ground from either side where applicable in an emergency. The drill should be practiced until the subject is familiar with it, and then at least 3, timed, rapid exits should be performed, using both sides of the cockpit as appropriate. At least 1 egress should be made under simulated night conditions. Any adverse interactions or snagging should be investigated. Where applicable at least 1 egress should be made via a miniature detonating cord (MDC) fired canopy.

(3) Emergency Sea Egress: Subjects should perform an emergency egress drill to simulate aircraft abandonment following ditching. Where appropriate, underwater escapes in the PPE under test should be performed with at least 1 test made at night or under simulated night conditions. The times should be recorded.

2. Effect on Escape System Functioning

Tests should be conducted to assess the effect of the PPE on escape and survival. Additional tests specific to ejection seats are grouped under paragraph 2.g., and where applicable, tests detailed here should be referred to those tests specified in paragraph 2.g.

a. Exit from Aircraft. The subject should simulate emergency air exits from the aircraft. Any adverse interactions or effects should be investigated. During these checks, the pockets should contain all items of equipment normally carried by aircrew during all types of flight. These tests should cover both ejection and static seats as appropriate. Manual bail-out tests should be performed in front of a blower tunnel as appropriate.

b. Parachute Suspension Checks. Where applicable an anthropometrically representative range of subjects should be suspended in all applicable PPE combinations in the seat/parachute harness with the seat kit attached and lowered as it would be during a parachute descent. The angle of suspension should be calculated from the parachute design measurements and the ability to reach and operate any parachute control (e.g., lift webs or steering lines) should be noted. The limitations of vision and head movement due to interaction of the head/helmet with the harness, risers, and PPE should be assessed. The life preserver should be inflated (both left and right handed in turn) by manual operation of the inflation head. Any interaction during operation and inflation should be investigated. Once the life preserver is fully inflated the limits of vision and head movement should be reassessed. Any limitation of the subject's necessary actions caused by the suspension and fully inflated life preserver stole(s) should be defined. The subject should perform the actions required to release the seat kit and then himself from the harness. The release from the harness should be repeated without first releasing the seat kit if appropriate. If applicable, seat kit release and release from the suspending harness should be undertaken using either hand. Any difficulties should be investigated and noted and the times taken to release should be recorded. The release procedure should also be attempted with the harness under load and without load, using subjects with very cold wet gloved hands. If applicable, release from the harness should be attempted single handed with each hand in turn to simulate the injured arm or hand case. At least one release should be attempted under simulated night conditions.

c. Drop Test. Subjects dressed in the appropriate PPE should perform drop tests in the appropriate parachute harness up to the G peak specified for the aircraft/parachute type but not exceeding +10G. The test method should ensure that the desired deceleration G is applied for a realistic time. This test should be followed by a 10 min suspension period with the seat survival kit initially attached and then lowered. Any adverse affects and PPE

interaction should be noted. Where a combined parachute and restraint harness is used, the harness should first be fitted into the seat and the subject strapped in, followed by releasing the harness from the seat. The tests described above should then be satisfied. These tests should be followed by drop tests to 25G using dummies dressed in the appropriate PPE.

d. Harness Release and Life Raft Operation. Harness suspension and, where a manual inflation mechanism is fitted, the life preserver inflation should be performed over water, and the subject in the harness should be dropped from a representative height into the water. The subject should be required to release the seat kit, divest himself from the harness or parachute, inflate the life raft, enter the life raft, and extract and simulate the use of the survival aids mounted on the life preserver and in the seat kit. A further test should be performed with the subject under simulated night conditions. Inflation of and entry into the life raft, etc., should be repeated several times to include at least one assessment of performance with, where practical, cold, gloved, and wet hands. Any difficulties or excessive delays in the performance of the sequence should be investigated and reported.

e. Winching. A test should be carried out to ensure that the PPE is compatible with helicopter winching equipment.

f. Parachute Dragging. An assessment of the operation of the parachute harness release fastening(s) under dragging conditions in water and on land should be made. These tests should be performed at dragging speeds of up to 15 mph on land and at either 5 or 10 knots in water depending upon parachute design. The water dragging test must be carried out with the life preserver inflated and deflated, and with the seat kit raised and lowered. Assessments should be made with subjects starting the land dragging tests in both prone and supine positions and dressed in the appropriate PPE. An assessment should also be made to ensure that the subject is able to rotate from a face-down to a face-up attitude in all configurations of seat kit and life preserver. The subject should wear gloves throughout dragging tests. For water dragging, the duration of drag should not exceed 10 sec when at the test speed.

g. Ejection Seats. The following tests are specific to ejection seats:

(1) Inversion. The subject dressed in the appropriate PPE and strapped into the seat should be inverted and any body movement recorded with the harness both locked and unlocked. The subject's ability to reach the seat pan or other firing handle(s) and other seat emergency controls should be checked. In the event of anti-G trousers and/or pressure garments being worn, one check should be made with the garments inflated to ensure that operation of the seat firing handle(s) is possible.

(2) Ejection Pathway. The ejection pathway should be investigated to ensure a clear passage for the full range of subject sizes with particular attention paid to buttock-knee and overall leg lengths. This should be done by winching a subject in the seat up the ejection seat rails sufficiently to enable an accurate assessment of the clearance between the seat, its occupant and the cockpit structure. Optimum limb restraint line length (if fitted) and

personal service disconnection should be determined by ejection seat rig tests and confirmed by representative tests in either a mock-up cockpit or aircraft. Where pressure garments/anti-G trousers are worn these should be inflated for this test. Where applicable an MDC fired canopy or empty canopy frame should be in position for these tests.

(3) Man/Seat Separation. Clean separation of the man from his ejection seat when he is being extracted by the parachute harness, or performing manual separation, should be examined in as realistic a manner as is possible. This can be satisfied either by subjects "rolling" out of the seat while suspended at varying angles or by using a rig to simulate extraction of the man by his parachute risers. If applicable, this test should include a functional check of the automatic activation of the emergency radio. Ground assessments should be supported by filmed evidence of ejection seat tests, defined in 2.g.(4).

(4) Performance. Ejection seats should be tested through the speed range defined for the aircraft type. Tests should use representative PPE on dummies of appropriate anthropometric dimensions. The effects of wind blast, ejection force, rocket-powered canopy jettison, MDC, or other canopy shattering or cutting or other through canopy systems should be assessed. Some air blast tests may be carried out on either commercial or laboratory wind tunnel/blast test rigs.

3. Environmental

These tests should show the effect of the environment on the PPE as a complete assembly.

a. Flight Acceleration. The subject dressed in appropriate PPE and strapped into the test seat installed in an approved centrifuge should be subjected to the maximum allowed airframe $+/-G_z$ defined in the aircraft specification. The ability of the subject to operate predefined essential controls and emergency systems under these conditions should be assessed and any adverse interactions noted.

b. Flight Vibration. The subject dressed in the appropriate PPE and strapped into his seat should be subjected to a vibration spectrum simulating aircraft flight. To obtain the vibration spectrum, aircraft flight vibrations should be recorded and fed back into a vibration facility. This should include a check using sinusoidal vibration over the frequency range 1 to 40 Hz at a peak of $+/-1G_z$, and from 5 to 20 Hz at a peak of $+/-2G_z$, to see if there are any critical frequencies causing interaction with the PPE. Any adverse effects or interaction should be noted.

c. Altitude Performance. The subject dressed in appropriate PPE and strapped into his seat should be subjected to a representative aircraft altitude profile in a decompression chamber. These altitude tests which are to include a simulated rapid decompression are to be related to the defined statement of operating intent for the aircraft. Any adverse effects of these tests should be noted.

d. Long Duration Wear. The subject dressed in appropriate PPE should simulate 24 hr standby, maximum duration cockpit standby, and maximum sortie duration. When anti-G trousers are worn, these should be inflated every 30 min to 5G equivalent pressure for a period of 30 sec throughout the sortie. Any adverse effects or interactions should be noted.

e. Thermal Conditions The thermal stress imposed by wearing the complete PPE should be assessed under specified maximum, minimum, and range of temperatures and humidity under conditions representative of the aircrew physical workload. These tests may be performed in conjunction with the long duration wear tests described in para 3.d.

f. In the Field. The performance of the subject and PPE while engaged in forward base operations and under escape and evasion conditions should be assessed. These checks should be performed during full trials in hot, cold, dry, and wet weather conditions. Any adverse effects should be noted.

g. In Flight. The PPE should be given a flight trial to confirm its acceptability under all conditions of routine flight, as applicable to the aircraft type(s).

RECORDING OF TESTS

Satisfactory completion of the described tests should be noted on a schedule of PPE tests as shown in Appendix B.

TEST AGENCIES

These PPE tests should only be carried out by approved agencies. Test agencies should not clear items of equipment developed by their own establishment unless they have the only test facility capable of performing a specific test. In this special circumstance, an outside agency should be appointed to monitor the test(s).

ANTHROPOMETRICALLY INFLUENCED TESTS

Tests 1a-1.d, 1.f., 2a-2g, and 3a-3g are anthropometrically influenced and should take account of the following test dimensions and be performed by subjects in the following ratio:

1 x small size	- i.e., no listed dimensions relevant to the test greater than 10th percentile.
1 x average size	- i.e., all listed dimensions relevant to the test between 25th and 75th percentile.
2 x large size	- i.e., no listed dimensions relevant to the test less than 90th percentile.

Whenever possible tests should include subjects near the anthropometric limits to the particular Service (e.g., 3rd and 99th percentiles or 5th and 95th percentiles) of dimensions relevant to the specific test. When such subjects are not available, at least 1 subject should be less than 10th percentile and another above 90th percentile in the relevant major parameters of aircrew size. When anthropometrically influenced problems occur, the number of subjects should be increased in the critical size range(s).

To determine fit and function of isolated items of the PPE, where the design measurement parameters are known, subjects should be selected to represent the anthropometric range of each specific size of each item of PPE being assessed.

Dimensions to be taken into account as appropriate to specific tests are detailed as follows:

(1) Sitting Height.

(2) Sitting Eye Height.

(3) Functional Reach (sitting) - horizontal and vertical.

(4) Buttock-Knee Length.

(5) Thigh Circumference.

(6) Chest Circumference.

(7) Waist Circumference.

(8) Bideltoid Breadth.

(9) Hip Breadth.

(10) Weight.

(11) Buttock-Heel Length.

(12) Stomach Depth.

(13) Stature.

(14) Knee Height

(15) Elbow-Fingertip Length.

(16) Head Breadth.

(17) Head Length.

(18) Head Circumference.

(19) Face Length.

(20) Face Breadth.

Note: Consideration should be given to the fact that the definitions and methodologies for each of the above dimensions may vary between the appropriate service agencies responsible for aircrew anthropometry.

TEST VEHICLE

Every appropriate crew position, aircraft type, and mark should be considered for tests 1.a. to 1.f., and 2.a., and final acceptance should be performed in production standard aircraft.

TEST ASSEMBLIES

Combinations of PPE to be considered for all tests should be performed in routine and chemical defense environments during summer, winter (wet/dry), and combat/cold weather conditions.

A chemical defense (CD) PPE is defined as any one of the above routine assemblies in conjunction with the appropriate chemical defense protective garments and equipment.

The complete schedule of tests referred to above should be repeated for any item/assembly of chemical defense protective equipment. Particular attention should be paid to the effect that PPE items/assemblies have on CD operating procedures in terms of Don/Doff drills and the transit of aircrew to and from the aircraft.

For any PPE, all the tests should be performed with and without anti-G suit, and air-ventilated/liquid-conditioned garments as appropriate. Personal armor should be worn where applicable.

DEVELOPMENT FLYING FEEDBACK

In addition to the above tests, the appropriate authority and PPE test agencies should maintain a close liaison with aircrew during development flying to ensure rapid feedback of comments on the PPE to the design authorities.

APPENDIX A

TABULATION OF THE ESSENTIAL FACTORS

The following is a tabulation of the essential factors which should be considered during the development and integration of aircrew clothing and equipment.

1. Define the Need

It is necessary to have a complete mission outline together with any additional specific needs.

Assess the working environment - Define the aircraft role

(1) Altitude

(2) G Performance

(3) Temperature range/Humidity

(4) Noise

(5) Vibration

(6) Toxic threats (*including any aircrew/aircraft environmental toxic substances*)

Geographical areas - Define the theater of operation

(1) Thermal environment - effect on cockpit

(2) Survival needs, including definition of the systems required for the physiological protection of the crewmember.

- type of oxygen delivery system
- type of pressure protective
- type of protective garments
- type of personal conditioning garments
- type of head protective equipment
- type of communication equipment
- type of harness
- need for parachute
- need for ejection seat
- need for flotation aids

- need for survival aids

Cockpit/Workspace Environment

(1) Define aircrew member(s) specific roles

(2) Cockpit thermal profile

(3) Cockpit altitude profile

- normal

- emergency

(4) Vibration profile

(5) Noise and communication profiles

2. Define the Population

a. Accurate knowledge of the appropriate relevant aircrew anthropometry

b. Define the aircrew size range to be considered, and any critical

c. Obtain representative range of subjects - ideally with operational

3. Define specifications

a. Functional specifications

b. Size and Form specifications

Reference to any relevant National/International standards and specifications

c. Secondary purpose

4. Produce Prototypes

5. Assess Prototypes

a. Function

(1) physiological

(2) ergonomic

b. Modify and re-assess

c. Produce pre-production prototype standard

6. Evaluate

a. Use representative population

(1) range

(2) expertise

b. Use geometrically accurate cockpit mock-ups

c. Use real environment

d. Evaluation of PPE

(1) As individual item - meet design requirements

(2) As part of total assembly -- Must not be incompatible in

- Function

- Fit

- Comfort

- Mobility

- Durability

(3) As suitable for population

(a) Size roll

(b) Fit

(4) As suitable for use in the workspace - meet requirements of the flying task and aircraft role

(a) Cockpit entry

(b) Evolve strapping-in procedures

(c) Examine normal postures

(d) Examine working postures

(e) Examine emergency ground and air egress

(f) Examine emergency ground and air egress

(g) Examine compatibility with NBC operating procedures

e. Normal posture

(1) comfort

(2) visual fields

(3) mobility

f. Working posture:

(1) functional reach of both arms and legs

(2) functional operations consistent with the flying task

(3) fields of view - internal and external to cockpit

(4) equipment interaction

g. Egress

(1) Normal

(2) Emergency - all types

- develop logical drill

- examine for proper release

- extract along ejection pathway

- roll-out of seat

- suspend in harness

- examine performance during representative test ejection profiles (windblast).

h. NBC operating procedures:

(1) Within cockpit - repeat workspace assessments

(2) Transit of aircrew to and from aircraft

(3) Don/Doff procedures - maintain safe operation under toxic threat, consistent with contamination control area procedures.

7. Field trials

a. Limited issue to selected users

b. Obtain knowledge of results

(1) questionnaires and reports

(2) verbal debrief

(3) observations

c. Incorporate modifications and re-trial

8. Issue to service

   a. Training

   b. Maintenance

      (1) replacement

      (2) repair

      (3) inspection

   c. Feedback

   d. Modifications

APPENDIX B

SCHEDULE OF AEA TESTS

AEA Item/Assembly

TEST NO.	TEST	TEST AGENCY	TEST REPORT NO.
1.a.	Dressing		
1.b.	Walk-Out and entry		
1.c.	Strapping-In		
1.d.	Normal Procedures [(1)-(4)]		
1.e.	Anthropometric Limitations		
1.f.(1)	Normal Exit		
1.f.(2)	Emergency Ground Exit		
1.f.(3)	Emergency Water Exit		
2.a.	Exit from aircraft during flight		
2.b.	Parachute Suspension Checks		
2.c.	Drop Test		
2.d.	Harness Release/Life raft operation		
2.e.	Winching		
2.f.	Parachute Dragging		
2.g.(1)	Inversion		
2.g.(2)	Ejection Pathway		
2.g.(3)	Man Seat Separation		
2.g.(4)	Ejection Seat Performance		
3.a.	Flight Acceleration		
3.b.	Flight Vibration		
3.c.	Altitude		
3.d.	Long Duration Wear		
3.e.	Thermal Conditions		
3.f.	In Field		
3.g.	In Flight		

Date:_____

NOTE: 1. Special comments should be entered in a "Remarks" column as necessary.

2. If a test is cleared by analogy, this should be stated in "Remarks."